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John Houbolt: The Unsung Hero of the Apollo Moon Landings

William F. Causey

"The choice of *how* to get to the moon was critical to meeting President Kennedy's goal of a lunar landing 'before this decade is out.' Bill Causey's deeply researched and clearly written book depicts how the persistence of one man, NASA engineer John Houbolt, decisively influenced the tortuous and contentious process of making that choice. This book nicely fills a glaring gap in the history of America's journey to the moon, and reminds us that the lunar journey was far from straightforward."

—John M. Logsdon, Professor Emeritus, Space Policy Institute, The George Washington University

"Causey's book joins the list of essential reading for people seeking to understand the forces that made possible the Apollo space program. He expertly recalls the venture from the perspective of the people who organized the expeditions, and the sole engineer who convinced the country's finest spaceflight minds that getting to the moon and back by 1970 required lunar orbit rendezvous. In the process, Causey paints a vivid picture of the inner workings of American government and the making of technical decisions in the mid-twentieth century."

—Howard McCurdy, Professor, American University, Washington, DC

"John C. Houbolt was another of the 'hidden figures' of NASA during the Apollo era. Bucking institutional blinders, Houbolt convinced the leaders of the space agency that lunar orbit rendezvous was the best way to conduct the Apollo program. William Causey's biography of Houbolt tells the fascinating story of how this lone engineer battled bureaucracy to help America achieve President Kennedy's vision, 'before this decade is out,' of 'landing a man on the moon and returning him safely to the earth.'"

—Roger Launius, author of *Reaching for the Moon: A Short History of the Space Race*

JOHN HOUBOLT

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JOHN HOUBOLT

The Unsung Hero of the Apollo Moon Landings

William F. Causey

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Cover image: NASA Image and Video Library (21 July 1969)—The *Apollo 11* Lunar Module ascent stage, with astronauts Neil A. Armstrong and Edwin E. Aldrin Jr. aboard, is photographed from the Command and Service Modules (CSM) during rendezvous in lunar orbit. The Lunar Module (LM) was making its docking approach to the CSM. Astronaut Michael Collins remained with the CSM in lunar orbit while the other two crewmen explored the lunar surface. The large, dark-colored area in the background is Smyth's Sea, centered at 85 degrees east longitude and 2 degrees south latitude on the lunar surface (nearside). This view looks west. The Earth rises above the lunar horizon.

The American, by nature, is optimistic. He is experimental, an inventor and a builder who builds best when called upon to build greatly.

John F. Kennedy, January 2, 1960, announcing his candidacy for president of the United States

The man with a new idea is a crank until the idea succeeds.

Mark Twain, *Following the Equator*, 1897

Contents

ABBREVIATIONS

AACB	Space Research and Technology Aeronautics and Astronautics Coordinating Board
ABMA	Army Ballistic Missile Agency
ARPA	Advanced Research Projects Agency
CIA	Central Intelligence Agency
DOD	Department of Defense
EOR	earth orbit rendezvous
ETU	Eidgenössische Technische Hochschule
GWS	Glennan-Webb-Seamans Project for Research in Space History
JFKPL	John F. Kennedy Presidential Library
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
LBJPL	Lyndon B. Johnson Presidential Library
LCF	Langley Central Files
LOR	lunar orbit rendezvous
LRC	Langley Research Center
MIT	Massachusetts Institute of Technology
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
NACA	National Advisory Committee for Aeronautics

NASA	National Aeronautics and Space Administration
NASM	National Air and Space Museum
NHRC	NASA Historical Reference Collection
PARD	Pilotless Aircraft Research Division
PSAC	President's Science Advisory Committee
RAE	Royal Aircraft Establishment

AUTHOR'S NOTE

In 1962 I spent my 13th birthday in bed with the flu. To help pass the time my parents bought me a thin book called *The Astronauts*, by Don Myrus, published in 1961. During the following week, I read that book cover to cover many times. I stared at the photographs of the Mercury astronauts training in their silver spacesuits and white helmets, and memorized the location of the dials and displays on the instrument panel of the Mercury capsule, as well as the capsule's orbital path around the earth. John Glenn was scheduled to be launched into orbit at the end of that week, and I counted down the hours with anticipation—now that I understood why it would be a momentous event. My tattered copy of *The Astronauts* still sits on my bookshelf today.

As I was growing up, I followed everything about the space program. I watched every launch (I was conveniently sick those days and had to stay home from school to recover in front of the television), recorded the events on my reel-to-reel tape recorder (who knows where that is now), and read every book about the space program. I knew the names of all the astronauts (even the second and third classes), the name of each capsule, and the flight plan for each mission. As a teenager, some days I would take the train from Baltimore to Washington, DC, to visit NASA Headquarters and obtain preflight press kits and astronaut photographs for upcoming flights. Back then, one could simply

walk into NASA Headquarters and take the elevator to the top floor, where the Public Information Office would gladly hand out material. One day I got off the elevator and literally stumbled into the press conference for the upcoming *Gemini 4* flight and got to see and meet astronauts Jim McDivitt, Ed White, Frank Borman, and Jim Lovell. To keep my classmates from thinking I had become a complete nerd, I played baseball (reasonably well), wore my hair longer, and went to school dances.

I remained interested in space during college and law school. I still followed every flight, and was irked when the Apollo-Soyuz Test Project flight in July 1975 competed with my study for the bar exam. On the 20th anniversary of *Apollo 11*, I read a book by Charles Murray and Catherine Bly Cox called *Apollo: The Race to the Moon* (Simon and Schuster, 1989). Early in the book they discuss the role of NASA engineer John Houbolt in NASA's decision to adopt lunar orbit rendezvous (LOR) as the mode for landing men on the moon. In a footnote, Murray and Cox said, "Houbolt was not the originator of the L.O.R. concept (nor did he claim to be), but his advocacy was crucial, probably decisive, in leading to the adoption of L.O.R. There is a fascinating doctoral dissertation yet to be written on this episode, however." Several years later I read an excellent book on NASA's Langley Research Center called *Spaceflight Revolution*, by James R. Hansen (NASA SP-4308, 1995). One of the chapters was about Houbolt and the LOR decision. My interest in the LOR story grew. I wanted to write that dissertation.

I started by taking a few days one summer to read Houbolt's papers at the University of Illinois at Urbana-Champaign, where Houbolt received his bachelor's and master's degrees in engineering. I spent hours reviewing material in dozens of carefully catalogued boxes—black-marbled composition notebooks from Houbolt's years in high school with pages of equations and comments in his meticulous block handwriting; every paper and report he wrote and delivered on a wide

range of topics about airplanes and spaceflight, including his papers on LOR; and even the menu and wine selection for the celebration dinner for the *Apollo 11* astronauts that Houbolt attended in Los Angeles in August 1969. My enthusiasm for writing my "dissertation" grew.

I decided that I had to interview Houbolt if I were to write a serious history of the LOR decision. I learned that he was retired and living in Scarborough, Maine, with his wife, Mary. I sent him a letter, saying that I was writing about the LOR decision and wanted to interview him on the topic. I included my phone number and invited him to call me if he was interested in meeting. Weeks went by, and there was no response; I figured my letter was one of many he must have received over the years. Then one day the light on my voicemail was blinking. The caller said, "Mr. Causey, this is John Houbolt. I received your letter, and I would enjoy meeting and talking to you." My wife and I were on a plane to Maine the following weekend.

John and Mary were very gracious, and we talked for hours, looking out at the spectacular Maine coastline. John showed me material about his NASA days that he had not donated to the University of Illinois, including the flag that was flown to the moon and given to him by the *Apollo 11* astronauts. I met with John several times over the next few years to talk about Apollo and the LOR decision. He became more comfortable talking about his career with NASA and the people he worked with. I sensed from our conversations that he was bitter about how he had been treated by many at NASA over the LOR issue, and that he wanted his side of the LOR story to be told. At some point, I noticed that John's health had begun to decline. I last saw John several months before he died in April 2014 at the age of 95.

PROLOGUE

On the morning of July 21, 1969, one day after Neil Armstrong and Buzz Aldrin walked on the moon, astronaut James Lovell spoke to them from Apollo Mission Control in Houston as the two astronauts stood in the lunar module *Eagle*. They were preparing to take off to join their fellow *Apollo 11* astronaut Michael Collins, who was orbiting the moon in the command module *Columbia*. Addressing the three astronauts, Lovell said, "Eagle and Columbia, this is the backup crew. Our congratulations for yesterday's performance, and our prayers are with you for the rendezvous."[1]

What followed was one of the most important moments in America's space program—the *Eagle*'s liftoff from the moon and reunion with *Columbia*, circling overhead in lunar orbit. This had never been done before. Prior to *Apollo 11*, astronauts had successfully performed rendezvous in earth orbit during Project Gemini, and in May 1969 the *Apollo 10* lunar module had descended to eight miles above the moon's surface and then rendezvoused and docked with the command module in lunar orbit before returning to earth. But this time lunar module *Eagle* would take off from the surface of the moon before attempting to locate and dock with *Columbia*. The next several hours would tell whether billions of dollars, hundreds of thousands of hours of work, and

years of planning would result in all three *Apollo 11* astronauts returning to earth, or whether only one of them would come home.

Armstrong and Aldrin were exhilarated after their brief but historic walk on the moon. After reluctantly climbing back into *Eagle* and stowing their rocks, cameras, and equipment, they took off their helmets and gloves and recounted their walk for Mission Control in Houston, describing the lunar terrain: the rocks and soil, the dozens of small sharp-rimmed craters that surrounded the lander, and the stark beauty of the lunar landscape and sky. Aldrin talked about the fine, gray moondust that he and Armstrong had tracked into the lander. It had a strange smell, like wet ash. After an hour or so, they tried to eat some bacon squares, peaches, and sugar cookie cubes and drink some orange and pineapple juice. They were hungry but still too excited and exhausted to eat.

Aldrin was beginning to think about how they would position themselves for a few hours of sleep in their tiny cabin when his eye caught something lying on the floor. It was a tiny black circuit breaker that looked like the pull-off top of a thin black pen. He picked it up and scanned the various panels of circuit breakers on the sidewalls of the cabin. Aldrin's heart skipped a beat when he noticed that missing on one of the panels was the switch that armed the ascent engine of the lander—*Eagle* could not take off if the switch did not work. Aldrin figured that at some point while suiting up for their moonwalk one of them must have brushed against the switch in their bulky suits and knocked it off. Aldrin showed Armstrong the broken switch.

They looked at each other, knowing full well what this meant. Aldrin promptly reported the problem to Mission Control. The flight controllers in Mission Control suggested they leave the breaker out for now; Mission Control would figure out what to do and report back—takeoff from the moon was still hours away. There was nothing Armstrong and Aldrin could do at the moment, so they decided to try

to sleep. But they were worried about the broken circuit breaker and hoped Mission Control would come up with a solution by the end of their sleep period.[2]

Armstrong tried to sleep in a makeshift hammock he strung over the top of the canopy of the ascent rocket engine in the cramped cabin. Aldrin curled up on the floor by the hatch that opened onto the ladder that led down to the surface. Both were unable to get comfortable in the tight space, and they also got cold. They donned their heavy spacesuits, gloves, and helmets; connected their suits to the *Eagle*'s environmental control system; and turned up the suit temperatures to keep warm. They tossed and turned, dozing on and off for about three hours. Overhead, circling the moon, Collins dozed somewhat better in the more spacious and warmer *Columbia*, wearing his lighter flight overalls, waking up at times to wonder whether he would see his fellow crew members again.

Unable to sleep any more, Armstrong and Aldrin stood up and began to prepare for takeoff from the moon. By this time, Aldrin had thought of the felt-tipped pen he had been using to take notes over the past few days; the pen tip was the perfect size to push the breaker in and arm the engine for liftoff. He tried the pen, and to his relief it seemed to fit. After reporting this to Mission Control, Aldrin put the broken switch in his small bag of personal items; the switch would make a great show-and-tell item if they ever made it home.

Satisfied that the pen would work, Armstrong and Aldrin completed their checklist of takeoff procedures with astronaut Ron Evans, the capsule communicator in Mission Control, who in a few years would go to the moon himself on *Apollo 17*. As the three went through the checklist methodically, Evans instructed Aldrin to turn off the rendezvous radar system and not use it during the beginning of *Eagle*'s takeoff from the moon. Aldrin was confused by this instruction; normally, the rendezvous radar would be used during the ascent to help locate *Columbia*. Aldrin did not know that during the past several

hours, Mission Control had determined that the rendezvous radar system, accidentally left on during *Eagle*'s descent to the lunar surface the day before, had caused the lander's computer system to overload and almost fail; Houston did not want to risk the computer failing during the insertion into lunar orbit. Evans told Aldrin that the radar system could be turned on once *Eagle* reached lunar orbit and was closing in on *Columbia*. Aldrin said he understood the instructions.

Finally, 124 hours and 23 minutes after *Apollo 11* had left Cape Canaveral, Evans informed *Eagle* that it was cleared for takeoff from the moon. Aldrin wryly responded, "Roger. Understand. We're number one on the runway."[3] Seconds later large metal cutters automatically severed the electrical and structural lines connecting the descent and ascent stages of the lander, the hypergolic propellants mixed in the combustion chamber, and the ascent engine came alive with hardly any motion or sound. At 1:54 p.m. (EDT) on July 21, 1969, Aldrin said, "Beautiful" as they lifted off from the moon.[4] Both astronauts were surprised at how quickly and silently *Eagle*'s 10,837-pound ascent stage left the moon; their knees buckled, and they held on to the side handrails for balance and support. "Nothing we had ever practiced in simulators could compare with our swift swoop upward," Aldrin later wrote.[5] Armstrong glanced out his window at the moment of liftoff and saw small bits of gold foil scatter in all directions and the American flagpole shake in the exhaust plume as *Eagle* rose from the lunar surface.[6] Despite the swift ascent, the lunar module "wallowed around" as it struggled to gain altitude; Aldrin later called it "a little unnerving."[7] During the ascent, Armstrong reported to Mission Control, "It's a pretty spectacular ride."[8]

Everything performed flawlessly as they gained speed. After three minutes, the lander's weight was down to 5,885 pounds, almost half what it had been at liftoff, as the engine continued to gulp fuel. Armstrong and Aldrin called out the names of the craters speeding by below. Armstrong, pleased that everything was going well, reported

to Mission Control, "We're going right down US 1"—the main highway running the length of Florida in 1969.[9] Seven minutes later, *Eagle* achieved an elliptical lunar orbit with its lowest point at 9.4 miles and the highest point at 46.7 miles; the latter was the same altitude as *Columbia*'s circular orbit around the moon.

As soon as Armstrong and Aldrin confirmed they were safely in lunar orbit, they started the complicated procedures to rendezvous with Collins. Over the next two hours, Armstrong slowly maneuvered *Eagle* into a nearly circular orbit to match *Columbia*'s. Three hours and two orbits after Armstrong and Aldrin lifted off the moon's surface, over the dark side of the moon and out of communication with earth, Collins spotted *Eagle*'s blinking whitetracking light 250 miles away. Armstrong then performed a procedure called terminal phase initiation by firing *Eagle*'s thrusters to shoot in a direct line for *Columbia*, and the two spacecraft closed at a rate of about 120 feet per second. Aldrin later wrote that this part of the ride was so steady it was like "riding on a monorail."[10] Armstrong finally spotted *Columbia*'s tracking lights. Inside *Columbia*, Collins donned his heavy suit, helmet, and gloves, according to his checklist, and turned on his window camera to film *Eagle* closing in. Aldrin likewise turned on the camera mounted in the window in *Eagle* that was pointed at *Columbia*. The final phases of the rendezvous were filmed from both vehicles for mission planners to study for future flights—and for the historical record.

As the two spacecraft moved closer together, Armstrong fired his thrusters in the opposite direction, slowing *Eagle* to a station-keeping distance of about 25 feet from *Columbia*. When Collins saw the earth pop over the moon's horizon, he quickly grabbed his still camera and took several photographs—the now-famous pictures show *Eagle*, the moon's horizon, and the earth in the same frame. They began to communicate with earth again as they came around the front side of the moon. "We're station-keeping," reported Armstrong, in his typical

monotone voice, indicating that the two spacecraft were facing each other and holding a constant distance between them.[11] The astronauts could hear in their earphones the applause erupting in Mission Control.

Despite their joy over the successful rendezvous, their work was not over; Armstrong and Collins had to dock the two spacecraft while still in lunar orbit. Sitting in *Columbia*'s left-hand seat, Collins kept focused on *Eagle* in the window in front of him. Armstrong focused on the instruments in front of him, avoiding the temptation to look out at *Columbia* through the small rectangular window above his head. Collins, who had the better view straight out *Columbia*'s window, performed the final docking maneuver that would lock the two spacecraft together as Armstrong kept *Eagle* steady, using his right hand to occasionally fire the small attitude jets positioned outside on the four quadrants of *Eagle*. Collins barely tapped his hand controller to gently nudge *Columbia* forward in order to push the probe on the nose of *Columbia* into the drogue opening on the top of *Eagle*. Once the probe was in place, Collins flipped a switch to swiftly retract the probe so that its 12 latches would catch and pull *Eagle* into the docking hole.

But there was a problem—a potentially serious problem. Collins reported to Mission Control that "all hell broke loose" when he threw the switch to lock the two spacecraft in place.[12] The latches on *Columbia* did not catch, and the much lighter *Eagle* swerved violently to the right and started to drift away. The three astronauts were surprised, but Collins quickly nudged *Columbia* forward again—this time a little harder—and the latches finally caught with a louder crunch and bang. *Columbia* and *Eagle* were successfully pulled together and locked.

Collins pumped up the cabin pressure in *Columbia* so that the air through the airlock would flow in *Eagle*'s direction when the hatches were opened. He wanted to make certain that any possible

Apollo Command Module as seen from the Lunar Module during LOR. Courtesy of NASA.

lunar contaminants brought onto the *Eagle* by Armstrong and Aldrin would stay in the lander and not drift into *Columbia*. For their part, Armstrong and Aldrin vacuumed up any remaining moondust still floating in the lunar module cabin. Once most of the moondust was captured, the hatches connecting *Columbia* and *Eagle* were opened, and Collins started the airflow into the lander. Three very tired but smiling astronauts shook hands and shared bear hugs. Capsule communicator Charlie Duke—who would later walk on the moon on *Apollo 16*—said, "We'd like to congratulate everybody on a successful rendezvous."[13]

Then the astronauts began the arduous task of moving boxes of moon rocks, spacesuits and helmets, and other items from *Eagle* into *Columbia*. In turn, small trash bags from *Columbia* containing empty food packages and urine and fecal bags were transferred to *Eagle*. About four hours after docking, with *Columbia*'s hatch bolted and the docking latches disengaged, Collins fired *Columbia*'s thrusters and slowly backed the command module away, leaving *Eagle* to drift away and eventually crash on the moon. "There she goes," Armstrong said with a tinge of sorrow in his voice.[14] Collins, referring to the Visitor Room overlooking Mission Control, said to Duke, "I imagine that place has cleared out a little bit since the rendezvous."[15] After some much-earned rest, the three *Apollo 11* astronauts could get ready to fire the large service module engine that would push them out of lunar orbit to begin their journey home.

More than ten years before Armstrong set foot on the lunar surface, NASA began planning to send men to the moon.[16] At first, shortly after NASA was created in 1958, the consensus was to send one big rocket with several astronauts to the moon, land and explore, and then take off and return the astronauts to earth in the same vehicle. A few people had a different idea. A small group of engineers at the Langley Research Center in Hampton, Virginia, led by John C. Houbolt, thought there was a faster, cheaper, and more reliable way to send men to the moon. Houbolt and his colleagues called it lunar orbit rendezvous (LOR). The LOR idea was first ignored, then criticized, and finally dismissed by many senior NASA officials, including Robert R. Gilruth, the head of Projects Mercury and Apollo; Maxime (Max) Faget, who designed the Mercury and Apollo spacecraft; and Wernher von Braun, who built the Saturn V rocket and promoted a third way to go to the moon, called earth orbit rendezvous (EOR). Nevertheless, the Langley group, led by Houbolt, continued to press the LOR idea. When President John F.

Kennedy in May 1961 made landing men on the moon and returning them to earth a national commitment, NASA then had to figure out how to do it. During the next two years, senior NASA administrators, engineers, and scientists fiercely debated the different methods to get astronauts to the moon and back. Houbolt argued that LOR was the only way to get men to the moon and back by the end of the decade, the deadline set by President Kennedy. Houbolt persisted in the face of overwhelming opposition, risking his career and reputation. NASA finally realized that Houbolt was right and adopted LOR as the way to send men to the moon.

This is the story of how NASA made that decision.

PART I

BEGINNINGS

CHAPTER 1

A YOUNG ENGINEER

John Cornelius Houbolt was born on April 10, 1919, in the small town of Altoona, Iowa, although his Air Force discharge papers list Des Moines as his birthplace. John, and his brother, Neal, and his sisters, Mary and Irene, were close growing up on the small family farm in Iowa, where life for children was hard and self-reliance was a necessity, not simply a virtue. Houbolt later admitted he was a stubborn person, claiming that he had inherited his "Dutch Stubbornness" from his parents, John and Henrica, first-generation Dutch immigrants. When Houbolt was six, the family moved to New Lennox, Illinois, and then to Joliet. Houbolt was solid Midwest America.[1]

Houbolt was a precocious child, and by the age of six—two years before another stubborn Midwest American named Charles Lindbergh made the first solo flight across the Atlantic Ocean—he was fascinated with the mystery of flight. In one of his first experiments in aerodynamics, he attached wings to his brother's baby buggy and pushed it off the front porch (without Neal as a passenger); he was surprised and disappointed when it crashed immediately to the ground. He thought maybe he had added too much weight to the wings. Undeterred, he later conducted

a "private study" by jumping off the roof of the family barn with an open umbrella to gain a better understanding of the principle of lift. Instead, he learned more about the force of gravity, landing with a hard thud; fortunately, he had had the foresight to place a pile of hay in the expected landing zone.

Houbolt's interest in flight was soon reflected in the building of model airplanes, a hobby shared by many boys at the time. He would design his model planes on graph paper—an early indication of his inclination toward engineering. By the time he entered Joliet Township High School, Houbolt's interest in airplane design had expanded to include technical mechanical drawing. Houbolt fitted a certain stereotype by drawing and writing everything with a mechanical pencil—a habit he kept for the rest of his life. Houbolt's interests also spilled over to science. In high school he wrote focused papers in black-and-white-marbled composition notebooks, with titles such as "The Earth's Magnetic Field," "The Concave Mirror," and the more advanced "Coefficient of Linear Expansion." Houbolt grew to love working with numbers and concepts, and he filled his early notebooks with equations, graphs, and charts made with precision and care. His early affinity for numbers is best reflected in another school project, in which he calculated the weight of the trusses, rafters, and columns in his high school building. His conclusion demonstrated his penchant for precision: he calculated the total weight to be 71,965.3 pounds. It was a prophetic project; Houbolt had no way of knowing that, years later, he would be called upon many times to defend his calculations for the estimated weight of a lunar lander, the major issue in the debate over the best method for landing men on the moon.

In the mid-1930s, with large segments of the country still struggling to escape the Depression, Houbolt's parents scraped together enough money to send their elder son to nearby Joliet Junior College. After a restless first year of college study, he convinced his parents to

let him apply for an in-state tuition program, and after his application was accepted, he transferred to the University of Illinois at Urbana-Champaign. Life in a larger city was challenging for the small-town sophomore; he found the same to be true for his studies. Houbolt uncharacteristically struggled with his first-semester math course; despite his fondness for numbers, the unnerving experience convinced him to switch to the civil engineering program rather than pursue a degree in physics with its math-laden curriculum.

Notwithstanding this change in plans, there was another side to college life in the big city that enabled Houbolt to grow as a person. The shyness that Houbolt had displayed in high school faded as he made new friends on the sprawling university campus. He was popular with his classmates, and his increasingly good looks, coupled with an inquisitive smile and twinkle in his eye, drew the attention of female students. Houbolt's intense devotion to study during the day frequently was capped by dinner with friends and an occasional movie at night; he had a fondness for John Wayne and Jimmy Stewart movies that was not always shared by his dates.[2]

Houbolt did well at Illinois and graduated in 1940 with a degree in civil engineering. He liked his studies—for him, the perfect blend of math, design, and construction—and he found Champaign-Urbana a relaxing place to live and a good environment for studying. He decided to stay there for two more years to get a master's degree in civil engineering. After receiving his master's in 1942, Houbolt mailed his résumé to several potential employers around the country, including the National Advisory Committee for Aeronautics (NACA) Langley Research Center in Hampton, Virginia. (The name NACA is pronounced by saying each letter—"the N – A – C – A.")[3]

One day in 1942, Dr. Gene Lundquist, head of Langley's Structural Dynamics Division (known simply as "Structures" around Langley), was reading through a stack of résumés. Lundquist was looking for new

engineers to fill the rapidly expanding needs of his department, and he particularly wanted to hire new college graduates with degrees in civil engineering because his division's work now involved more than just aerodynamic issues. Houbolt's résumé caught his eye, and he put the application aside on a separate pile that deserved a second look. Soon, Houbolt received a call from Lundquist's office asking whether he could come to Langley for an interview.

To prepare for the interview, Houbolt learned as much as he could about Langley and Lundquist, including reading a 1931 technical report written by Lundquist. Lundquist liked Houbolt's calm demeanor and seriousness and found the young graduate's humility refreshing in an environment full of pushy engineers and arrogant scientists who thought they knew everything—including how best to run his division. Lundquist also appreciated that Houbolt's responses to his questions were well thought out, succinct, and on target. Lundquist believed he knew talent when he saw it, so he offered Houbolt a job on the spot. Houbolt accepted it immediately.[4]

Houbolt's first assignment at Langley was to study propellers and their behavior in turbulent wind environments. Although his degree was in civil engineering, Houbolt quickly grasped the elemental concepts and language of aeronautical engineering, and he dove into his work with his usual zest and focused attention. He spent hours on the second floor of the Langley library, located in one of the several red brick buildings in the West Area of Langley Field, poring over technical reports and notes, as well as dozens of designs, charts, and graphs. He took copious notes in his working papers with his mechanical pencil in his neat block handwriting. Houbolt's supervisors praised his work, saying he could find simple solutions to hard problems, the highest compliment for an engineer. Within a short period, Houbolt was assigned to analyze the more complex problems of flutter, gust and landing loads, and acoustics, all of which he handled with thorough attention to detail and accuracy.[5]

John Houbolt's Langley photograph. Courtesy of NASA/Langley Research Center.

Houbolt soon developed a small but close network of friends at Langley. His best friends were Pat Chiarito, Roger Anderson, and Joe Kotanchi. (Many years later Kotanchi would design the stand for the American flag that Neil Armstrong and Buzz Aldrin planted on the moon.) Together, the four engineers rented a house at 55 Cherokee Road in Hampton, which they dubbed Club 55, only ten minutes from the main gate at Langley. They carpooled to work to save gas, usually ate together in the Langley cafeteria, and spent many hours in the hallways talking about the projects they were working on at the moment. They shared making dinner, enjoyed repairing broken fixtures around the house, and, on rare occasions, would drag out a dust mop or vacuum cleaner, usually when female guests were expected. There were weekend boat outings in Hampton Roads from the local public dock just a few blocks from Club 55, and Houbolt developed a fondness for and skill at boating that stayed with him for the rest of his life. Although Houbolt would occasionally suggest the food or wine to take on the weekend boat outings, and sometimes helped organize the softball games in the neighborhood, he was not the center of life at Club 55, nor did he want to be.

Like most of the unmarried engineers at Langley, Houbolt balanced his busy workdays with occasional date nights at the movies or Friday night dinners out, or maybe a sailing outing in Hampton Roads on Sundays with other couples. John Wayne and Jimmy Stewart were still

his favorite movie actors, and the latest Alfred Hitchcock thriller was added for date night. Houbolt's intense commitment to work, however, prevented him from becoming entangled in a serious relationship—at least for a couple of years.

Mary Morris grew up in a comfortable upper-middle-class family in Winston-Salem, North Carolina, about 275 miles southwest of Hampton, Virginia. Her father owned an upscale furniture store, furniture being one of the staple industries in the state. Her family's social and economic position allowed her to go to college after the war, one of the few women in North Carolina to do so; she attended the Women's College of the University of North Carolina at Greensboro. There, she made friends quickly with her engaging mind, ready smile, and razor-sharp wit. But like most women in college at the time, she hoped to meet "Mr. Right, get married and have a family." Unless a woman wanted to be a teacher, a secretary, or a nurse, she did not go to college to have a career.[6]

But Mary was a bit different. She wanted to experience more of the world before she settled down. During her freshman year of college, she realized that she was good with numbers; she majored in math and also took the one course in physics offered at the Women's College. Mary was extremely popular with her classmates, and many would come to her with their problems—both scholarly and personal—seeking her very adult-sounding advice. To get away from provincial North Carolina, Mary and her close school friend Sue Johnson spent a summer in New York City. While there, Mary took a course at Columbia University. Although Mary would later not remember the name of the course, she loved living in the big city, going to plays, strolling the parks, and window-shopping in the stores along Madison Avenue.

When Mary and Sue graduated from the Women's College with degrees in mathematics, they decided to search for a job together. In

1946 women with college math degrees were much sought after by employers to help with the restructuring of the postwar economy, particularly in electronics and aviation. It was not long before Mary and Sue got a call from Dr. Gene Lundquist at Langley.

In 1946 the only female engineer employed at Langley was Kitty O'Brien Joyner, who had joined the NACA in 1939 after becoming the first woman to graduate with an engineering degree from the University of Virginia.[7] Most women at Langley worked as secretaries, but a few women with college degrees in math were hired as "computers"—they converted the equations and test data provided by the male engineers into charts and graphs, which the engineers used to continue their aerodynamic studies and prepare their technical reports. Other than being women, the computers all shared one attribute: they were good at their work.[8]

Lundquist knew that Langley management wanted division chiefs to recruit computers from the University of North Carolina Women's College; Langley had had good experience in the past employing women from the college as computers. When Lundquist inquired in the spring of 1946 about new candidates to hire, the school reported that two of the best math graduates that year were Mary Morris and Sue Johnson. There was no need for interviews; Lundquist immediately extended offers to Mary and Sue to be computers for the Structures Division. Mary told Sue, "If you'll go, I'll go."[9] They both joined Langley in 1946. Mary, 21 years old, was offered an annual salary of $1,440.[10]

When they arrived in Hampton, Mary and Sue decided to save on expenses by living with several other women who worked at Langley. They all lived in a large house they dubbed the Bird Cage and drove to work together in the "Computer Pool," as they called it. Before long, some of the computers in the Bird Cage started to date some of the engineers living at Club 55. The two houses, not far from each other, became known as the sorority and fraternity row of Hampton. Mary

and Sue loved their new jobs, but they could never get used to the roar of the jets taking off nearby at Langley Field.

Mary was assigned to work with five other women in Lundquist's Structures Division in the West Area of the expanding Langley campus. They worked on the second floor of the building that housed the Structures Division; the engineers worked on the first floor. Mary's supervisor, Lillie Belle Evans, was a pleasant woman who sat at a large desk at the front door as one entered the open floor of workers. Evans was an excellent supervisor; she instilled in her computers the need for precision, accuracy, and timeliness in their work as well as a sense of discipline and decorum. Mary sat at a gray metal desk with a lamp, a notepad, and a Marchant calculator, a rather cumbersome device that could multiply and compute square roots much faster than by hand. Usually an engineer would bring a project to Evans, who would assign it to one of her computers to make sure the workload was divided evenly among the six women. The work involved making calculations based on the tapes and films generated by the engineers from wind tunnel tests, and converting the calculations to data that the engineers and modelers could use to continue and refine their studies. Some of the computers did their work on a slide rule, but Mary preferred the Marchant calculating machine. Despite the snobbish attitude that some engineers had toward the work performed by the computers, that work was critical to the success of Langley's mission.[11]

One day in the summer of 1946, John Houbolt noticed a new woman working in the computer section of Structures. John thought she was attractive and wanted to get to know her. People in the building began to notice that John would occasionally sneak up the steps with rolled papers in his hand, as if he were taking a new assignment to Lillie Belle Evans on the second floor.[12] It was not out of the ordinary for an engineer to walk upstairs to the computer section—in fact, Langley

Female "computers" at Langley in 1948. Courtesy of NASA/Langley Research Center.

management had instructed the male engineers to take their work assignments to the female computers; management did not want the female computers walking the buildings or campus looking for the male engineers who claimed to have assignments for them. This way, at least as far as work in Structures was concerned, Evans could keep an eye on who was coming to the second floor with assignments for her six female computers. Evans lately had noticed John coming up the stairs more often.

John wanted to meet the new computer. One day, he asked a colleague to go up to the second floor and distract Evans for a few minutes by asking her some questions. The friend accepted the assignment; he knew exactly what John had in mind. John gave his coworker a few minutes, then quickly went up the stairs, again with papers in hand, to find Evans talking earnestly to his colleague. Evans watched John out of the corner of her eye, well aware of the ruse that was taking place, as John made a beeline for Mary, the new computer.

John introduced himself to Mary and asked how she liked working at Langley. When he finally got around to asking her for a date, Mary said yes but suggested that they double-date in case things did not go well. John was perplexed and somewhat annoyed by this response, but he agreed. Their first date was a week later. After dinner at a local restaurant, the two couples went sailing on John's small Hampton One Design boat, which he had acquired over the past winter. Soon after Mary carefully crawled into the boat, she noticed small holes drilled under the seats and near the floorboards. No water could come in through them, but the holes looked odd. When she asked John about the holes, he replied that he wanted the boat to be as light as possible so that it would travel faster through the water. Mary found this strange, but because she knew nothing about boats, she let it pass. She then began to think what she could do to make sure this was her only date with John. He was pleasant but just seemed too odd and out of the ordinary.

The Hampton late spring night was unusually warm and humid. When they returned to the dock and Mary was getting out of the boat, she looked at John and jokingly said that for two cents she would jump in the water to cool off. John, never one to pass up a dare, reached into his pocket and handed her two pennies. Without missing a beat, Mary took off her shoes and jumped in the water. Mary hoped this silly stunt would bring a quick end to their relationship, but as John and the other couple helped pull Mary out of the water, everyone broke into loud and sustained laughter. On the spot, John was convinced this was the girl for him. John's jovial and carefree reaction to the incident changed Mary's mind about him.

They started dating regularly, now by themselves. They began to enjoy each other's company a great deal—Mary, the practical one, and John, the adventurer, a perfect blend of personalities. They spent more time on the boat, with Mary being careful to stay out of the water. Mary would endure the John Wayne and Jimmy Stewart movies; John

would try to enjoy the plays and live musical performances that Mary insisted they also see. They began to spend all their free time together. But, oddly, they never talked about work—the unspoken and visible division between male engineer and female computer was still part of their relationship. They did everything else together; they even made appointments to have their wisdom teeth pulled at the same time. They soon became inseparable, and on December 7, 1948, John Houbolt and Mary Morris were engaged to be married.

Other than being in love, John and Mary had another reason for becoming engaged. John had been offered an opportunity to serve as an exchange scientist for six months with the Royal Aircraft Establishment (RAE), the British aircraft research facility in Farnborough, England. Mary encouraged John to accept the offer, thinking it was a way for them to marry and honeymoon in Europe. John was scheduled to leave for Farnborough in a few weeks. They decided to become engaged before John left for England.

Houbolt arrived in England in early 1949 and found Farnborough to be a fascinating place. Located in the northeastern section of Hampshire, Farnborough was rich in history. Founded in Saxon times, Farnborough was recorded in the Domesday Book of 1086, the "Great Survey" of England and Wales conducted by William the Conqueror to identify land redistribution after the Norman conquest to calculate taxes to be paid to the Crown. French emperor Napoleon III is buried there, and for a short time, T. E. Lawrence—better known as Lawrence of Arabia—lived there. And Sir Frank Whittle conducted his studies leading to the development of the first jet engine with the RAE at Farnborough. It was a once-in-a-lifetime engineering opportunity for Houbolt.

Houbolt spent his time at the RAE discussing aeronautical ideas with British engineers and drafting several research papers on a variety of topics. He would venture into the English countryside on weekends,

observing the architecture and thinking about his upcoming marriage to Mary. While John was in England, Mary continued her work as a computer at Langley. Mary mostly kept to herself, methodically doing her work and occasionally seeing a movie with female friends or improving her bridge game with the military families who lived in the area. Although she stayed busy, Mary missed John, and they kept in touch regularly by writing letters and sharing news—John describing how different Farnborough was from Hampton, and Mary reporting on how life in Hampton remained the same. They decided that Mary would come to England at the end of John's tour.

They were married on June 14, 1949, in the quaint red brick North Camp Methodist Church in Farnborough. For their honeymoon, John and Mary took the train to London and spent a few days there before crossing the English Channel and going to Lucerne, Switzerland, which they found magical. From Switzerland they toured Italy, France, and Holland for several weeks before sailing back to the United States on the ocean liner *America*.

John and Mary returned to Hampton and fell back into their routine at Langley—but now married. John transferred to the Dynamic Loads Division, where he continued to study airflow over aircraft, finding the work no different than before he left; the space race would not invade Langley for another eight years. Mary returned to her job as a computer in Structures, finding the old, reliable Marchant computer was still the machine of choice to make calculations. John still worked on the first floor of the Structures building in the West Area, and Mary still worked with the other computers on the second floor just above him—with Evans still serving as an organizational buffer, although now not as strictly as before for John and Mary. Despite their marriage, John and Mary decided to be professional during the day, and the only time they saw each other, apart from evenings at home, was driving to and

John and Mary Houbolt's wedding picture, June 14, 1949. Courtesy of Mary Houbolt.

from work every day and occasionally having lunch in the cafeteria. The only thing they noticed that was different about Langley was the noise of the two new huge wind tunnels, which they could hear from their house two miles away.

Soon Mary became pregnant and decided to stop working. The decision was a big one for Mary; she was good at what she did, had many close friends at Langley, and could have had a long and profitable career at a time when most women did not have careers. But raising a family full-time was more important to her. After leaving Langley, she spent her time getting the house ready for a new addition to the family.

Mary Cornelia was born on November 7, 1950. The pregnancy had been easy, and John and Mary were excited new parents. Mary had never seen John smile as much as he did when their daughter, whom they called Neil, was born. But like most new parents, they found raising their daughter to be more of an effort than they had imagined. Then, before they knew it, their second daughter was on the way. Joanna was born on September 25, 1953. Their third daughter, Julie, was born on April 20, 1955. John was never disappointed that they did not have a son; he loved the girls dearly, and he and Mary provided a secure and comfortable home for them in Hampton. But soon John had the opportunity to go back to Europe to obtain his doctorate in engineering, and he and Mary liked the idea of having the girls spend a few months in Europe.

In December 1956 John Houbolt, the son of an Iowa farmer, who was working on high-speed aircraft at Langley, and Ray Bisplinghoff, the son of a flour-mill owner and a distinguished aeronautical engineer at the Massachusetts Institute of Technology (MIT), were granted the Rockefeller Public Service Award to study for their doctoral degrees at the renowned Eidgenössische Technische Hochschule (ETU; the Swiss Polytechnic Institute) in Zurich, Switzerland. The ETU, founded in 1854, was a world-recognized university for science, technology, engineering, and mathematics. Rated one of the top universities for engineering and technology in the world, it has produced 21 Nobel Prize winners, with its most famous student being Albert Einstein.

John and Mary were running late as they hurried through the long carpeted hallways of the Shoreham Hotel in Washington, DC. They were searching for the ballroom where a luncheon program was being held for the recipients of the Rockefeller Public Service Award, including John, to receive their award certificates. As they started to walk quickly down one hallway in what they thought was the right direction, a man was walking just as fast toward them. He also appeared to be lost. He asked whether they knew where the Rockefeller Awards luncheon was being held. He said he was one of the speakers at the program and appeared embarrassed that he was lost. Mary recognized his face and voice right away from television—he was Senator John F. Kennedy.

The three finally stopped someone and found out where the luncheon was being held. They quickly headed in the right direction, walking down another long corridor, with diminutive Mary trying to keep up with Houbolt on one side and Kennedy on the other. Once Houbolt realized the identity of their companion, all three chatted as they scurried along the hallway. John and Mary found the senator friendly and engaging; Mary could not get over how handsome Kennedy looked in person. When the three arrived at the ballroom,

the attendees were just moving to their tables, with cocktails already in hand. Kennedy immediately was surrounded by people and was soon lost in the crowd. John and Mary were left standing alone before they went off quietly and unnoticed to find their table. They did not even have a chance to say goodbye to the US senator from Massachusetts.[13]

John and Mary sailed to Zurich in 1957 with Neil, Joanna, and Julie (who was only two years old) to live for several months while John obtained his doctorate. They also took their car, an unusual thing to do in those days, so that they could drive around Europe. Ray Bisplinghoff and his wife flew to Switzerland from Boston a week later, and the Houbolts picked them up at the Zurich airport.

Because Houbolt and Bisplinghoff came from two of the world's most respected scientific and engineering institutions, they were not required to attend classes to get their degrees, but they decided to go to the first class anyway just to see what it was like. The class was taught in German, of course, and they could not understand anything that was said, except that they heard the word *Stadt* several times, which they knew meant "city." They were perplexed that the professor did not write any mathematical equations on the blackboard or mention any aeronautical or mathematical terms they might recognize. During the first five-minute break, they asked a classmate why the word *Stadt* was being used all the time, only to learn that they were in a class on urban planning. They did not return to the classroom after the break, nor did they attend any classes thereafter.

Houbolt and Bisplinghoff were only required to write a doctoral dissertation to receive their degrees. They were assigned Dr. M. Rauscher as their program advisor. Houbolt had written so many technical papers in his work at Langley that writing his dissertation was not particularly difficult. He completed it in four weeks. Houbolt's dissertation—

"A Study of Several Aerothermoelastic Problems of Aircraft Structures in High-Speed Flight"—was not all that different from any technical paper he had written at Langley.

Mary typed John's paper in their small Zurich apartment after the children had gone to bed. This had been the plan even before they left Hampton, but they did not think to bring along their own portable typewriter; they would simply rent one in Zurich. Mary was an excellent typist, but she did not realize that German typewriters were slightly different from American typewriters. John's paper was full of equations, with lots of x's, y's, and z's and dozens of mathematical symbols. To Mary's horror, the German typewriter had the x, y, and z keys in different locations on the keyboard, and it took Mary far longer to type John's dissertation than it did for him to write it. Mary also had to deal with some disgruntled neighbors as she typed. Her table was on a wood floor with no carpeting. After a few hours of typing, the neighbors below banged on their ceiling with a broom handle to get Mary to stop making so much noise late at night. John and Mary were extremely embarrassed and the next day took their downstairs neighbors a bottle of wine to apologize.

Houbolt and Bisplinghoff eventually received their doctorates after their dissertations were approved; they were not sure how closely they were read, but Dr. Rauscher, their advisor, seemed pleased. The Bisplinghoffs came over to the Houbolts for a celebratory dinner. During dessert, Mary walked in with two small paper graduation caps she had placed on a pillow to present to the new doctors of philosophy. Under John's hat was Mary's graduation gift—a Swiss watch. When John returned to Langley, he always wore his watch, and he changed the nameplate on his desk to read "Dr. John C. Houbolt."